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U.S. NUCLEAR REGULATORY COMMISSION

Office of Nuclear Reactor Regulation
Attn: R. W. Reid, Chief
Operating Reactors Branch N
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Sir:

Three Mile Island Nuclear Station, Unit 1 (TMI-1)
Operating License No. DPR-50
Docket No. 50-289
Response to NUREG-0737 Items II.K.3.1, II.K.3.2, and II.K.3.7

Enclosed please find B & W Generic Report which addresses Items II.K.3.2 and II.K.3.7 of NUREG-0737. We have reviewed this report and have determined that it is applicable to TMI-1 with the exception of the following two items: the unreliability assumed for the Emergency Feedwater (EFW) System is higher than the TMI-1 EFW System; and number of openings of the PORV assumed to occur for steam generator tube rupture is excessive. In spite of these two exceptions, the report is conservatively acceptable for TMI-1 in that the assumptions overestimate the probability of PORV opening and a loss of coolant accident via the PORV.

Based on the results of this B & W Report there is no need for a PORV automatic Isolation System as identified by Item II.K.3.1 of NUREG-0737.

Sincerely,

H. D. Hukill
Director, TMI-1

HDH:LWH:lma
Enclosure
cc: H. Silver
L. Barrett
R. Jacobs
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B. H. Grier

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REPORT ON POWER-OPERATED RELIEF VALVE

OPENING PROBABILITY AND JUSTIFICATION FOR

PRESENT SYSTEM AND SETPOINTS

- Submitted to Satisfy Requirements of

NUREG-0737, Items II.K.3.2 and II.K.3.7

Document No. 12-1122779

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1.0 INTRODUCTION AND SUMMARY

NUREG-0737, "Clarification of TMI Action Plan Requirements," November 1980, required that a report be submitted which provides the information identified in Items II.K.3.2 and II.K.3.7. Specifically, NUREG-0737 requested the following information/justifications:

1. II.K.3.2
   - o Compile operational data regarding pressurizer safety valves to determine safety valve failure rates
   - o Perform a probability analysis to determine whether the modifications already implemented have reduced the probability of a small break LOCA due to a stuck-open PORV or safety valve a sufficient amount to satisfy the criterion ($<10^{-3}$ per reactor year), or whether the automatic PORV isolation system specified in Task Item II.K.3.1 is necessary.
2. II.K.3.7
   - o Perform an analysis to assure that the frequency of PORV openings is less than 5% of the total number of overpressure transients.

This report is submitted in compliance with NUREG-0737 and demonstrates that the requirements of NUREG-0737 are met with the existing Power-Operated Relief Valve (PORV), Safety Valve and High Pressure Trip Setpoints and that no automatic isolation system is required.

2.1 Evaluation of PORV Opening Probability During an Overpressure Transient

An evaluation of the probability of PORV opening has been performed. Two separate analyses have been performed. The first is an analytical estimate, the second is an analysis based upon operating experience.

2.1.1 PORV Opening Probability Based Upon Analyses

A series of calculations have been completed using best estimate numbers to estimate the probability of PORV opening. Wherever possible, these calculations were based on operating plant data in an attempt to provide realistic estimates for the analyzed events. The following paragraphs summarize the results and calculational basis for the analysis.

The probability of the PORV lifting during a loss of feedwater (LOFW) or turbine trip is approximately 3.9×10^{-6}/Rx-Yr for plants with a PORV setpoint of 2450 psig and 3.9×10^{-3}/Rx-Yr for plants with a PORV setpoint of 2400 psig. The latter setpoint is presently applicable only to Davis-Besse 1. These probabilities are based on the assumptions that the high pressure trip setpoint is 2300 psig with a standard deviation of 1.4 psi and that the actual setpoint at which reactor trip occurs is a random variable which is normally distributed. The small standard deviation is based on the fact that the PORV and RPS actuation points are not completely independent; i.e., they share a common source; i.e., sensor and instrument string. Thus, these parts of the string errors are perfectly correlated and cancel one another in the analysis. Other parts of the relevant string error are not correlated and it is upon these that the 1.4 psi standard deviations are based. In a similar fashion, the actual opening setpoint of the PORV is also assumed to be a random variable with a normal distribution. The assumption of normality for the actuation of either the high pressure trip or the PORV is just an assumption; no data is available to justify or deny the validity. The RCS pressure rise above the RPS high pressure trip setpoint (hence referred to as "pressure rollover") during a LOFW or turbine trip was determined by a combination of plant data and engineering analysis. Pressure rollover data from the operating plants (Table 2.1-1) was compiled from available data. However, these data points represent situations in which the PORV could open, thus decreasing the amount of pressure overshoot. Therefore, it was necessary to correct for the PORV opening, since we are interested in the situation in which it remains closed. This was an accomplished by benchmarking the CADD code to a transient in which the PORV was isolated. After satisfactory duplication of this transient, the code was rerun modeling proper functioning of the PORV. The resulting pressure correction to the rollover data was 17.4 psi. The rollover data itself was tested and is statistically acceptable as normally distributed. It has a mean of 9.2 and a standard deviation of 27.52 psi. The presence of negative values in this data set indicates that the RPS trip setpoints have frequently been set low. Since the data reflects actual operating experience, the use of the negative values can be justified in the analysis.

Using the above data and assumptions, a Monte Carlo simulation of the relation

$$\text{PORV} - \text{RPS} - \text{EXCESS} - \text{BIAS} = \text{SAMPLE}$$

was conducted. The terms in the above relation are defined as follows:

PORV - PORV setpoint, a normally distributed random variable

RPS - High pressure trip setpoint, also a normally distributed random variable

EXCESS - Pressure follover, a randomly distributed normal variable

BIAS - A constant (17.4 psi) defined by analysis which compensates the rollover data for the fact that the PORV will remain closed.

Six thousand sample values of the above alogrithm expression were calculated using the SAMPLE code. A negative value of the above expression implies the PORV opens. In the computer trials, no negative values in 6000 instances were observed.

It was then assumed that the random variables described above are independent in the probabilistic sense, so an analytic approach was applied. The sum or difference of several independent normal distributions is also a normal distribution with mean equal to the algebraic sum of the means and standard deviation equal to the square root of the sum of variances. In this case, the mean is

$$2450 - 2300 - 9.23 - 17.4 = 123.37 \text{ (except DB-1, } = 73.37)$$

and standard deviation is

$$\sqrt{(1.4)^2 + (1.4)^2 + (27.52)^2} = 27.59 \text{ (for DB-1,} = 27.59)$$

The probability that the PORV will open during an overpressure transient is 3.9×10^{-6}/Rx-Yr (for DB-1 this value is 3.9×10^{-3}/Rx-Yr). The statistics show that we can be 99% confident that at least 99.99% of all LOFW and turbine trip high pressure transients will not open the PORV for the PORV set at 2450 psig. For a setpoint of 2400 psig, the statistics indicate a 99% confidence that more than 99.9% of the overpressure transients will not result in opening the PORV.

2.1.2 PORV Opening Probability Based Upon Operational Data

NUREG-0667, "Final Report of the B&W Reactor Transient Response Task Force," contained a listing of reactor trips (148) with PORV actuations prior to the TMI-2 accident. Since the accident at TMI-2 approximately 59 trips have occurred on B&W designed plants. Approximately 42 of these trips would have lifted the PORV with the old setpoints. Of the 190 trips that would have lifted the PORV with old setpoints, three of these events would have lifted the PORV with the new setpoints. In addition the modifications that have been made to the plants since those transients would have precluded PORV actuation given the same initiating events on those plants and the new setpoints. Based on these data, it is estimated that the present PORV opening probability is less than 1.6% for an overpressure transient, which is less than the 5% requirement stated in II.K.3.7 of NUREG-0737.

TABLE 2.1-1

PRESSURE ROLLOVER DATA

Trip #	Power, %	Peak Pressure, psig	Rollover, psig
1	95	2355	0
2	90	2385	+30
3	25	2400	+45
4	20	2385	+30
5	90	2390	+40
6	32	2345	-10
7	40	2360	+5
8	40	2352	-5
9	92	2375	+20
10	15	2365	+10
11	35	2400	+45
12	13	2370	+15
13	14	2355	0
14	38	2380	+25
15	98	2410	+55
16	72	2400	+45
17	100	2340	-15
18	100	2340	-15
19	100	2390	+35
20	100	2330	-25
21	98	2325	-30
22	15	2355	0
23	9	2370	+15
24	30	2345	-10
25	99	2350	-5
26	16	2295	-60

2.2 Evaluation of PORV and Safety Valve Reliability

2.2.1 Safety Valve Failure Rate History

There have been three cases where pressurizer safety valves were lifted on B&W plants. None of these cases resulted in failure of the safety valve to reseat. Because of the few data points, no estimate was made of the safety valve failure rates.

2.2.2 Evaluation of Small Break LOCA Probabilities/Need for PORV Isolation System

The contribution to the probability of a SB LOCA from an open PORV was estimated by two methods. The first was an analysis effort, the second was based strictly upon operational data. The results are discussed below:

2.2.2.1 Small Break LOCA Probability Calculations

The probability of a stuck open PORV is the product of the probability of being demanded open times the probability of failing open on demand. The raising of the PORV setpoint has reduced the number of demands and thus the probability of being in the stuck open state. The point estimate for PORV SB LOCA probably (variation not estimated) is calculated to be 5.04×10^{-4} per reactor year which complies with II.K.3.2 requirement that the probability of stuck open PORV SB LOCA does not significantly impact the probability of SB LOCA from all causes (1×10^{-3} per reactor year). The initiators of PORV actuations have been grouped into five categories along the associated frequency of each category. Details on how the values are calculated are contained in Table 2.2.2-1.

1. PORV opening on overpressure transient	3.9×10^{-6}/Rx-Yr
2. PORV opening on transient with delayed aux. feed	1.4×10^{-3}/Rx-Yr
3. PORV opening on operator action under ATOG guidelines	1.58×10^{-2}/Rx-Yr
4. PORV opening due to instrumentation control faults	5×10^{-3}/Rx-Yr
5. PORV opening from additional consideration from II.K.3.7	1.8×10^{-3}/Rx-Yr
TOTALS	2.40×10^{-2}/Rx-Yr 2.61×10^{-2}/Rx-Yr(DB)

This total is then multiplied by the probability of the PORV sticking open on demand.

Note that all plants except Davis Besse (Crosby PORV) have Dresser valves; however, the entire B&W operating plant experience was used to arrive at a generic PORV sticking open probability as follows: There have been ten stuck open PORV events, five of which could be classified as mechanical failure of the PORV (the other five were basically installation errors). Using all these five failures in determination of future frequency is considered conservative since two of the failures (OC-3,6/13/75 and CR-3, 11/75) were rectified by design changes, another (TMI-2, 3/28/79) cause is unknown. OC-2, 11/6/73 could be considered as a burn-in failure and the

DB-1, 10/13/77 event is a Crosby valve. Using five failures in 250 demands results in a value of 2×10^{-2} to fail to reclose on demand. This value is considered conservative not only due to the inclusion of all five failures but also the number of demands is probably much higher than 250. There have been 148 documented PORV openings on reactor trips; however, there is not a listing of PORV demands when the reactor did not trip (e.g. ICS runback) nor is consideration given to transients that could have actuated the PORV numerous times during an event. The value of 250 demands is conservatively used here. An analysis was also performed to include values for other than mechanical failure that keep the PORV open. The results of this analysis is summed with the mechanical contributor (2×10^{-2}/d) to arrive at the value for failure to reclose on demand (2.1×10^{-2}/d).

Probability of PORV small break LOCA equals:

$(2.4 \times 10^{-2})\ (2.1 \times 10^{-2}/d) = 5.04 \times 10^{-4}/Rx\text{-}Yr$

$(2.61 \times 10^{-2})(2.1 \times 10^{-2}/d) = 5.48 \times 10^{-4}/Rx\text{-}Yr$ (DB)

2.2.2.2 Small Break LOCA Probability Based Upon Operational Data

As discussed in Section 2.1.2, there have been three events which with the revised setpoints would have actuated the PORV. However, the plants have been reconfigured (e.g., upgrades on aux. feedwater, control circuitry of PORV, NNI power sources, AC power sources) so as to reduce the probability of these PORV actuations. Conservatively estimating that one event could occur in the 45 years of B&W plant operation, yields a probability of occurrence of 2.22×10^{-2}/Rx-Yr.

The previous section gave a PORV failure probability of 2.1×10^{-2}/d. Therefore the probability of a PORV small break LOCA equals:

$$(2.22 \times 10^{-2} d/Rx\text{-}Yr)(2.1 \times 10^{-2}/d) = 4.7 \times 10^{-4}/Rx\text{-}Yr$$

which is less than the 1.0×10^{-3}/Rx-Yr criterion.

3.0 CONCLUSION

Both the analytical prediction and the estimate based on historical data result in values for a stuck open PORV for all causes which meet the requirements given in II.K.3.2. Note that no credit has been assigned for the operator closing the block valve given an open PORV. Analytical predictions (given proper auxiliary feedwater response) result in a value less than .01% of PORV openings for overpressure transients (taking into account the most limiting non-anticipatory trips) and historical data shows the frequency to be less than 1.6% which satisfies the criterion (less than 5%) specified in II.K.3.7.

Since the requirements of II.K.3.2 and II.K.3.7 are met with the current PORV configuration and set point it is not necessary to address the requirement for an automatic block valve closure system per II.K.3.1.

Table 2.2.2-1

1. The probability of a PORV opening on an overpressure transient from Section 2.1.1

   for plants with PORV setpoint of 2450 — 3.9×10^{-6}/Rx-Yr

   for plants with PORV setpoint of 2400 (DB) — 3.9×10^{-3}/Rx-Yr

2. The PORV opening probability in a transient with delayed aux. feed

   A value of 1.0 was assigned for PORV opening probability if aux. feedwater was not supplied. A value of 1.4×10^{-3}/Rx-Yr for loss of all feedwater was referenced from a B&W calculation which used average unavailability as calculated in the generic aux. feedwater reliability studies (BAW-1584) in conjunction with generic EPRI data on loss of main feedwater frequency and loss of offsite power frequency.

   On completion of the ongoing aux. feedwater reliability analysis (AP&L, SMUD, FPC) more specific values can be applied to those plants. 1.4×10^{-3}/Rx-Yr

3. The PORV opening probability on operator action under ATOG guidelines

   There are 3 events that call for operator opening of the PORV: a) Loss of All Feedwater. This contribution is already counted in 2 above; b) Small LOCA. Not applicable to

Table 2.2.2-1 (Cont'd)

this calculation since the plant is already in a small LOCA; c) Steam Generator Tube Rupture (considered smaller than small LOCA as defined in II.K.3.2 so argument of b) does not hold): The demand on the PORV given a tube rupture varies depending on whether offsite power is available or lost. If offsite power (Reactor Coolant Pumps) is available, only one PORV opening is required, whereas in the loss of offsite power scenario as many as 23 PORV openings are required.

The value calculated assumes that the probability of Steam Generator Tube Rupture considered with a LOOP event is small (no causal effect of LOOP or Steam Generator Tube Rupture) and therefore, the WASH-1400 of 1×10^{-3} for a LOOP given a reactor trip is used in the calculations. There have not been any tube ruptures in the cumulative B&W experience, due to the limited number of years experience. A Chi-square 50% confidence value with 0 failures is rather high (1.54×10^{-2} Rx-Yr).

Table 2.2.2-1 (Cont'd)

1.54×10^{-2}/Rx-Yr x 1 demand (offsite power available) 1.54×10^{-2}/Rx-Yr.

1.54×10^{-2}/RX-Yr

x10^{-3} offsite power loss/event

x23 demands (offsite power lost) 3.54×10^{-4}/Rx - Yr.

1.58×10^{-2}/Rx - Yr.

In the final calculation of probability to reclose, it should be noted that no adverse effects of the 23 demands in the loss of offsite power case on PORV operability is assumed.

4. PORV opening due to instrumentation control faults

This has been estimated at 5×10^{-3}/ reactor year. This value assumes that power supply faults and other control deficiencies have been corrected by each utility. 5×10^{-3}/Rx - Yr.

5. PORV opening probability from additional considerations from II.K.3.7

There are overcooling transients that initiate HPI and operator failure to throttle or terminate flow before the PORV setpoint is reached. There have been 8 overcooling transients that initiated

Table 2.2.2-1 (Cont'd)

HPI in 392 reactor trips. The current frequency of reactor trips is 6 trips/ Rx-Yr per plant. In this event sequence, the operator has approximately 4 minutes from time of HPI initiation until PORV setpoint is reached. The operator failure rate to terminate or throttle HPI flow is based on having ATOG in place (1.5×10^{-2}/d - based on NUREG-CR-1278 with moderately high stress). The overall probability of this sequence is therefore estimated to be 6 trips/Rx-Yr x 8/392 overcooling events/trip x 1.5×10^{-2} = 1.8×10^{-3} Rx-Yr

N.A. for DB

TOTALS 2.40×10^{-2}/Rx-Yr.

2.61×10^{-2}/Rx-Yr.

Note that these values are dominated by the conservative analysis of steam generator tube rupture. Analytical studies could be performed to obtain a more realistic value. Also note that the calculation for category 4 did not include operator or maintenance induced faults, such as the DB event of 10/27/80.